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Telomers (n=3) of Vinylene Carbonate with Tetrachloromethane as Novel Synthetic Intermediates for Aldo-heptoses and -octoses[1]

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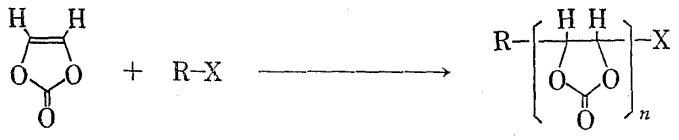
Stereochemistry of four isomeric telomers (n=3) (**3**), arising from the free-radical telomerization of vinylene carbonate with carbon tetrachloride, was unequivocally established as all *trans* addition forms (**3a, b, c** and **d**), based on their conversions to the enol-phosphates (**4**) and the heptitols (**8**). Synthetic potential of the telomers (**3**) for aldo-heptoses and -octoses has been shown by transforming for example the isomer **b** into "racemic" D-glycero-L-gulo- and D-glycero-D-ido-heptoses and D-threo-D-ido-octose in reasonable yields.

Keywords——telomer; vinylene carbonate; stereochemistry; racemic heptose (DL-heptose); racemic octose (DL-octose); tri- and di-chloromethyl group;

Previous papers[3] in this series have described the smooth free-radical telomerization of vinylene carbonate (**1**) in the medium of polyhalomethanes to permit a one-step stereoselective formation of type **2** telomers, among which n=1 and n=2 products have been successfully utilized as key intermediates in the total synthesis of aldosugars of trioses to hexoses[3–5] as well as in the preparation of oxazolidones[6] and phospholipid analogues.[7] The n=3 telomers isolated in stereohomogeneity are of particular significance as a potential source of biologically unique seven- and eight-carbon sugars, of which some have been isolated from natural sources such as certain bacteria and plants in the states of aldoses and/or ketoses,[8] though the biological significance of their natural occurrence seems not to have been fully recognized.



1 **2** (n=1, 2, 3⋯)

This paper deals with stereochemistry of four isomeric n=3 telomers arising from stereoselective radical reaction of vinylene carbonate and carbon tetrachloride, and their transformation into aldo-heptoses and -octoses in such short steps as previously employed for pentoses and hexoses from the n=2 telomers.[4]

1) Part XII in the series, "Studies on Telomers and Oligomers of Vinylene Carbonate." A part of this work has appeared in preliminary form; Y. Nii, T. Kunieda, and T. Takizawa, *Tetrahedron Lett.*, 2323 (1976). Part XI: N.Mitsuo, T.Kunieda, and T.Takizawa, *Chem. Pharm. Bull.* (Tokyo), **26**, 1501 (1978).
2) Location: *Hongo, Bunkyo-ku, Tokyo 113, Japan.*
3) T. Tamura, T. Kunieda, and T. Takizawa, *Tetrahedron Lett.*, 2219 (1972); *idem, J. Org. Chem.*, 39, 38 (1974). For a review, T. Kunieda and T. Takizawa, *Heterocycles*, **8**, 661 (1977).
4) T. Takahata, T. Kunieda, and T. Takizawa, *Chem. Pharm. Bull.* (Tokyo), **23**, 3017 (1975).
5) T. Matsuura, T. Kunieda, and T. Takizawa, *Chem. Pharm. Bull.* (Tokyo), **25**, 239 (1977).
6) T. Matsuura, T. Kunieda, and T. Takizawa, *Chem. Pharm. Bull.* (Tokyo), **25**, 1225 (1977).
7) N. Mitsuo, T. Kunieda, and T. Takizawa, *Chem. Pharm. Bull.* (Tokyo), **26**, 1493 (1978).
8) cf. L. Hough and A.C. Richardson in "Rodd's Chemistry of Carbon Compounds," S. Coffey, ed., Elsevier, Amsterdam, 1967, Chapter 23.

Telomerization of vinylene carbonate and carbon tetrachloride in the molar ratios of 1: 3, 1: 5 and 1: 7 followed by careful chromatography on silica gel gave 1.4%, 6% and 4% total-yields of four stereoisomeric $n=3$ telomers (**3a**, **3b**, **3c** and **3d** in order of separation), respectively, in addition to lower and higher telomers.[3] Isomer **3b** was the most abundant and telomers **3a**, **3c** and **3d** were in order of isolation yields.

Stereochemistry of $n=3$ Telomers

Treatment of the $n=3$ telomers (**3**) with tri-methyl and -ethyl phosphites in boiling toluene resulted in the smooth formation of the same type of *trans* enol-phosphates ($J_{a,b}=$ 12.0 Hz) as described previously for the $n=2$ telomers,[9] although paucity of pure sample prevented such transformation from the isomer **3d**. Thus, isomers **3a**, **3b** and **3c** gave the phosphates **4a**, **4b** and **4c** in moderate to high yields (50—70%),[7] respectively, of which the latter two were identical with regard to the IR and NMR spectral data as well as chromatographic behaviors, indicative of the configurational difference only at the terminal carbonate ring C of the telomers **3b** and **3c**. Product **4a** was distinctly different from the above phosphates.

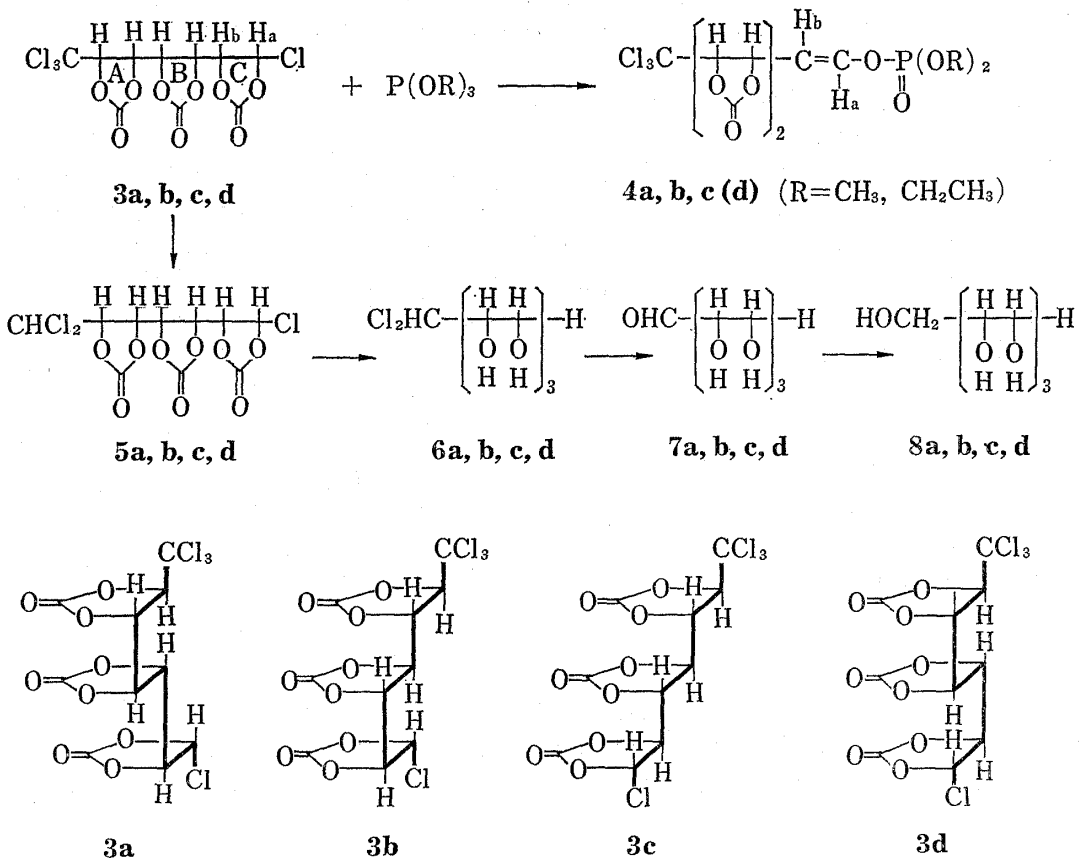


Chart 1

On the other hand, the telomers **3a**—**d** were successfully transformed into the heptoses **7a**—**d** by three-step procedure involving selective photolysis in tetrahydrofuran to the dichloromethyl compounds **5a**—**d** followed by borohydride reduction and subsequent hydrolysis with aqueous silver nitrate. The conditions have been shown to be satisfactorily applicable to the present system to negligible extent of the undesirable side-reaction such as epimerization.[4] The heptoses **7a**, **7b**, **7c** and **7d** derived from the isomers **3a**, **3b**, **3c** and **3d**, respectively,

9) N. Mitsuo, T. Kunieda, and T. Takizawa, *Chem. Pharm. Bull.* (Tokyo), **25**, 231 (1977).

without isolation in purified forms, were reduced to the heptitols **8a**, **8b**, **8c** and **8d**, which could be identified as *threo* glycero-galacto-, *erythro* glycero-ido, *threo*(*meso*) glycero-ido- and *erythro* glycero-galacto-heptitols[10] by gaschromatographic (1.5% QF-1, 2% XF-1105) com-

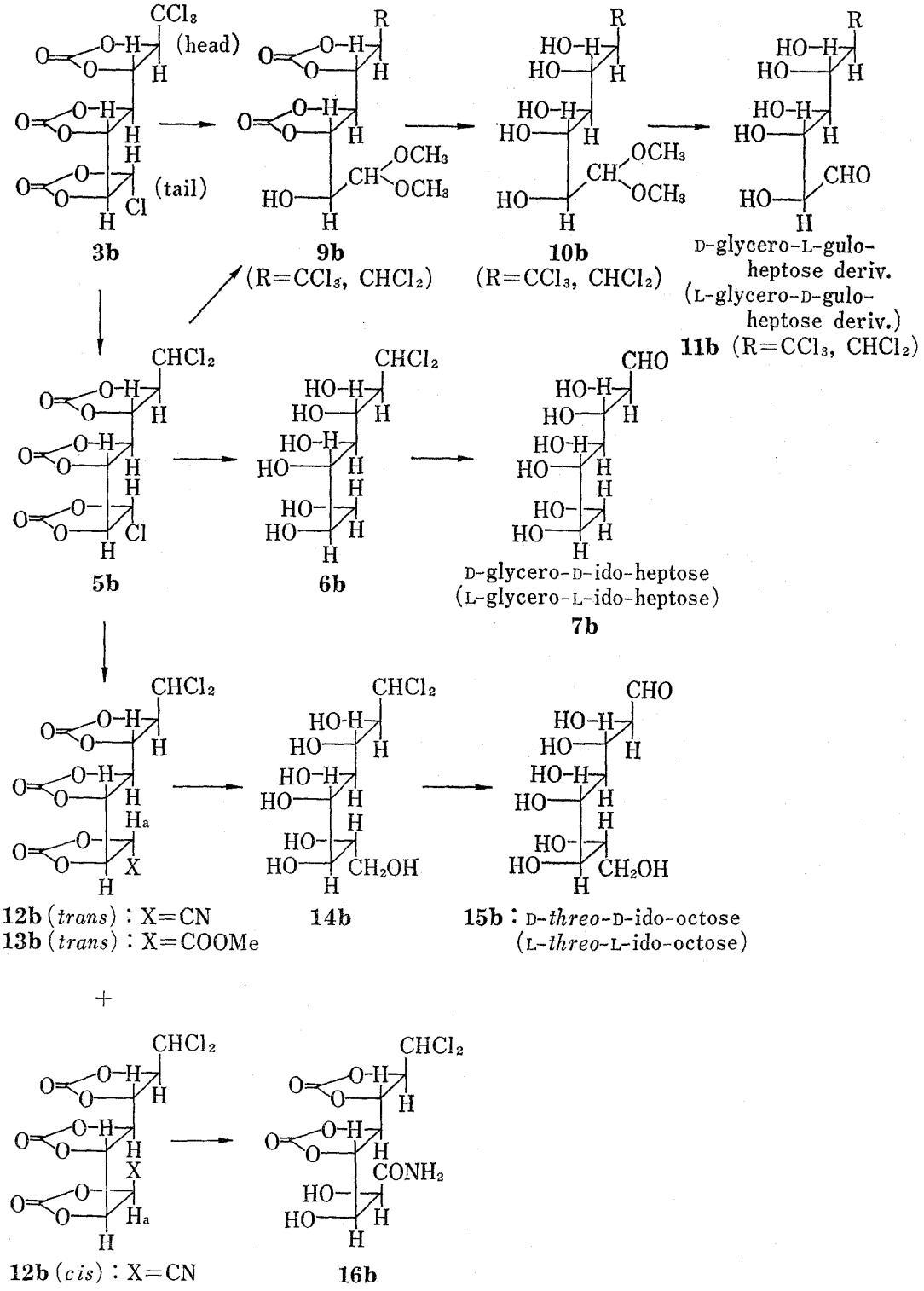


Chart 2

10) This paper uses the prefixes *threo* and *erythro* which mean the relationships between the configurations at C_5 and C_6, since an application of the rule (Biochemistry **10**, 3983 (1971)) to "racemic" heptoses and higher mono-saccharides seems to be somewhat confusing and inadequate. Thus, *threo* glycero-galacto-heptose means a 1:1 mixture of D-glycero-L-galacto-heptose and L-glycero-D-galacto-heptose.

parison[11] with authentic specimens,[12] D-glycero-L-galacto-,[12a] D-glycero-D-ido-,[12b] *meso*-glycero-ido-[12b] and D-glycero-D-galacto-heptitols,[12c] respectively.

On the basis of the above findings, the aldoses **7b** and **7c** must be *erythro* glycero-ido- and *threo* glycero-ido-heptoses[10] and hence, by taking account of the small coupling constants ($J_{a,b}$=2.0 Hz) between *Ha* and *Hb*, indicative of *trans* configuration,[3] isomers **3b** and **3c** could be stereochemically assigned as *trans*-"*anti*"-*trans*-"*syn*"-*trans*[13] and *trans*-"*anti*"-*trans* "*anti*"-*trans*[13] forms, respectively, as shown in Chart 1.

Assumed that such a trans-addition mechanism is operative in this free-radical telomerization as substantiated in the n=1 and n=2 telomers,[4] compounds **7a** and **7d** may be *threo* glycero-galacto- and *erythro* glycero-galacto-heptoses,[10] respectively, and therefore, *trans*-"*syn*"-*trans*-"*anti*"-*trans*[13] and *trans*-"*syn*"-*trans*-"*syn*"-*trans*[13] configurations could be given to the telomers **3a** and **3d**, respectively (Chart 1).

Thus the unequivocal evidence has been provided for *trans*-stereochemistry of all the low telomers ($n \leqq 3$) isolated so far.

It has now become feasible to convert the telomers to the biologically interesting polyalcohols involving heptoses and octoses with definite configurations. Such a conversion from the most easily-available isomer **3b** will be provided as a typical example.

Conversion of Telomer 3b to Heptoses

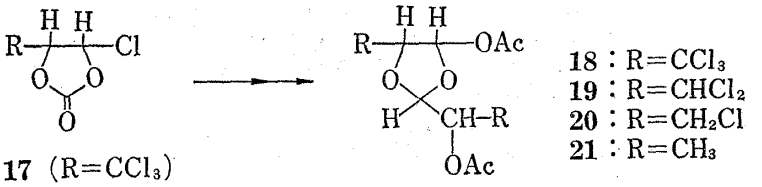
Eight kinds of racemic aldo-heptoses may be obtainable from the four n=3 telomers by the conversion of the head or tail carbons to the aldehyde function (Chart 2).

Halogen-free aldo-heptoses can be prepared by the route which involves the selective reduction of trichloromethyl group to dichloromethyl group followed by hydrolysis as described above. Thus, telomer **3b** gave *erythro* glycero-ido-heptose **7b** (30% over-all yield), characterized as the hexa-acetate (mp 150°), presumably β[14]-pyranose whose favored conformation would be the Cl(D) (or 1C(L)) form, having H-1 and H-5 axial, and H-2, H-3 and H-4 equatrial (and therefore 2,3 and 4-acetoxy groups oriented axially), based on the comparison of the NMR spectral data with those of D-ido-pyranose pentaacetate.[15] The *erythro* glycero-ido-configuration was confirmed as the heptitol which was identical with an authentic specimen[12] with regard to the gas-chromatographic behaviors.

In the alternative route, the tail terminal carbon is smoothly hydrolyzed to the formyl group *via* the acetal as a key intermediate, though direct acid- or base-hydrolysis of the telomer to such aldose is less satisfactory due to the side reactions such as epimerization and degradation. Telomer **3b** and the dichloromethyl derivative **5b** underwent the smooth ring-opening at the terminal position with methanol to give the acetals **9b**, which afforded 7,7,7-trichloro- and 7,7-dichloro-7-deoxy-*threo*-glycero-gulo-heptoses (**11b**),[16] respectively, by complete deblocking with base and acid.

Polyhalomethyl groups could be reduced stepwise to methyl group by the familiar radical-mediated reactions using organotin hydrides[17] as demonstrated in the following model system. Protected 3,3,3-trichloro-3-deoxy-glyceraldehyde dimer[5] **18** derived from n=1 telomer **17**

11) T. Imanari, Y. Arakawa, and Z. Tamura, *Chem. Pharm. Bull.* (Tokyo), **17**, 1967 (1969).
12) Kindly supplied by Dr. N.K. Richtmyer and Mr. E. Zissis of the National Institutes of Health, U.S.A. *a*) J.B. Laforge, *J. Biol. Chem.*, **41**, 251 (1920); *b*) J.W. Pratt, N.K. Richtmyer, and C.S. Hudson, *J. Am. Chem. Soc.*, **74**, 2210 (1952); *c*) G.Bertrand, *Compt. rend.*, **149**, 225 (1909).
13) The terms, *trans-syn*, *trans-anti*, *cis-syn* and *cis-anti* have been employed for the configurational definition of the telomers in this series for convenience. *cf.* ref. 3.
14) This only means a 1,2-H *cis* relationship, but not β-configuration.
15) N.S. Bhacca, D. Horton, and H. Paulsen, *J. Org. Chem.*, **33**, 2484 (1968). It has been commonly observed with pyranose sugars[16] that the favored conformation is not necessarily the chairlike conformer having the greater number of bulky substituents oriented equatorially.
16) C.V. Holland, D. Horton, and J.S. Jewell, *J. Org. Chem.*, **32**, 1818 (1967); L.D. Hall and J.F. Manville, *Carbohyd. Res.*, **4**, 512 (1967).
17) H.G. Kuivila, *Synthesis*, **1970**, 500.



(4-trichloromethyl-5-chloro-1,3-dioxolan-2-one) was UV-irradiated in tetrahydrofuran to give dichloromethyl compound **19** which was then reduced with organotin mono- and di-hydride[18] to give mono-chloromethyl- and halogen-free derivatives (**20** and **21**), respectively.

Thus, this provides a feasible route to 7-deoxy-*threo*-glycero-gulo-heptose from isomer **3b**.

Preparation of Octose

Treatment of the dichloromethyl derivative **5b** with sodium cyanide in the presence of tetrabutylammonium bromide as a phase transfer catalyst[4,19] gave the cyanides **12b** (98%) as a mixture of *trans* and *cis* isomers whose NMR spectrum showed doublet peaks in equal intensity at δ 5.56 (J=4.0 Hz) and 5.70 (J=9.0 Hz) attributable to *Ha*-proton. The isomers could not be separated stereohomogeneously by chromatographic means as well as fractional crystallization. The isomeric mixture was treated with methanolic hydrogen chloride to afford the methyl ester **13b** which would be derived exclusively from *trans* nitrile **12b**, since it has been observed on the cyanide from n=2 telomers[4] that *trans* isomer undergoes smooth conversion to the ester, while *cis* compound results in a complicated mixture including the amide and the ring-cleaved products. Other products could not be fully characterized except the amide **16b**, probably derived from *cis*-**12b**.

Conversion of dichloromethyl- and ethoxycarbonyl-groups to formyl and hydroxymethyl functions afforded *erythro* threo-ido-octose **15b**,[10] characterized as the heptaacetate. Identity was achieved by the reductive conversion of the acetate to the octitol which was identified as *erythro* threo-ido-octitol[10] by gas-chromatographic (1% XF-1105) comparison with an authentic specimen.[20]

Experimental

The physical data were obtained as follows; melting points (uncorrected) on a Yanaco micro-melting point apparatus; IR spectra on a JASCO-IRA-I spectrometer; GLC data on a Hitachi 163 gas chromatograph; NMR spectra on a Hitachi R-24 spectrometer at 60 MHz using Me_4Si as internal standard; mass spectra on a JEOL MS-SG-01 by direct injection.

5-Trichloromethyl-5″-chloro-[4,4′: 5′,4″-ter-1,3-dioxolan]-2,2′,2″-trione (3a—d) (n=3 Telomer of Vinylene Carbonate with Carbon Tetrachloride)——In an analogous manner to the procedure described earlier,[3] free radical telomerization of **1** and carbon tetrachloride in a molar ratio of 1: 5 gave four isomeric n=3 telomers **3a** (2.6 g, mp 244°), **3b** (4.3 g, mp 230°), **3c** (1.0 g, mp 290°) and a mixture[21] (0.7 g) of **3c** and **3d** in 6% total yield (best yield obtained so far). The telomers were identical with the authentic compounds[3] previously prepared with regard to the IR and NMR spectra.

Dialkyl 2-(2,2′-Dioxo-5′-trichloromethyl-[5,4′-bi-1,3-dioxolan]-4-yl)vinyl phosphates (4a, b, c)——General Procedure: A mixture of the telomers **3a-c** and triethyl (or trimethyl) phosphite (3-5equivalent mol) was refluxed in toluene (16 ml) for 30—70 hr in a sealed tube. The reaction mixture was evaporated *in vacuo*. The resulting oil was chromatographed on silica gel with CH_2Cl_2–acetone (98: 2 and 96: 4) as eluting solvents to give *trans* enol-phosphates **4a—c** as colorless crystals (or oil). The phosphates thus obtained had the following properties.

18) Y. Morishima, K. Fujisawa, and S. Nozakura, *Polymer Letters Ed.*, **14**, 467 (1967).
19) J. Dockx, *Synthesis*, **1973**, 441; E.V. Dehmlow, *Angew. Chem.*, Int. Ed., **13**, 170 (1974); R.A. Jones, *Aldrichimica Acta*, **9**, 35 (1976).
20) Kindly donated by Mr. E. Zissis of the National Institutes of Health, U.S.A. *cf.* M.D. Maclay, R.M. Hann, and C.S. Hudson, *J. Am. Chem. Soc.*, **60**, 1035 (1938).
21) This mixture was routinely used as a source of isomer 3d, since it was quite difficult to separate the isomers stereohomogeneously.

4a (R=C_2H_5): an oil (51% yield), IR (neat) 1830, 1680, 1250, NMR ($CDCl_3$) δ 6.92 (d-d, J=12 Hz, J=8 Hz, 1H), 5.50 (d-d, J=12 Hz, J=10 Hz, 1H), 5.3—4.4 (m, 4H), 4.14 (q, J=7 Hz, 4H), 1.37 (t, J=7 Hz, 6H). **4a** (R=CH_3): mp 149—151° (from CCl_4–CH_2Cl_2), 68% yield, IR (KBr), 1822, 1680, 1272, NMR ($CDCl_3$) δ 6.90 (d-d, J=12 Hz, J=8.5 Hz, 1H), 5.50 (d-d, J=12 Hz, J=9 Hz, 1H), 5.10 (t, J=8.5 Hz, 1H), 5.10 (d, J=4 Hz, 1H), 4.80 (d, J=4.5 Hz, 1H), 4.55 (d, J=7.5 Hz, 1H), 3.80 (d, J=12 Hz, 6H). *Anal.* Calcd. for $C_{11}H_{12}Cl_3O_{10}P$: C, 29.92; H, 2.74. Found: C, 30.04; H, 2.74. **4b** (R=C_2H_5): mp 136° (colorless needles from benzene–*n*-hexane), 54% yield, IR-(KBr) 1830, 1680, 1250, NMR ($CDCl_3$) δ 6.90 (d-d, J=12 Hz, J=8 Hz, 1H), 5.54 (d-d, J=12 Hz, J=9 Hz, 1H), 5.2—4.4 (m, 4H), 4.14 (q, J=8 Hz, 4H), 1.36 (t, J=8 Hz, 6H). *Anal.* Calcd. for $C_{13}H_{16}Cl_3O_{10}P$: C, 33.23; H, 3.41. Found: C, 33.39; H, 3.45. **4b** (R=CH_3): mp 197—199° (from CCl_4–$CHCl_3$) (72% yield)[7] **4c** (R=C_2H_5): mp 136.5—137° (colorless needles from benzene-*n*-hexane) (18% yield). The IR spectrum (KBr) was identical with that of **4b** (R=C_2H_5). **4c** (R=CH_3): mp 199° (from *n*-hexane-benzene) (32%). The IR spectrum (KBr) was identical with that of **4b** (R=CH_3).

5-(Dichloromethyl)-5″-chloro-[4,4′: 5′,4″-ter-1,3-dioxolan]-2,2′,2″-trione (5a,b,c,d)——General Procedure for Photo-reduction[22]: Solutions of 3a—c (*ca.* 0.03 M) in tetrahydrofuran (THF) were irradiated in a quartz vessel without filter with a high-pressure mercury lamp for 3—5 hr. The solvent was removed *in vacuo* and the products **5a—c** were purified by chromatography on silica gel (CH_2Cl_2) followed by recrystallization from acetone-CH_2Cl_2.

5a: colorless crystals, mp 233—233.5° (74%), IR (KBr) 1840 1820, 1810, NMR (CH_3CN) δ 6.58 (d, J=2 Hz, 1H), 6.22 (d, J=4 Hz, 1H), 5.20 (m, 5H). *Anal.* Calcd. for $C_{10}H_7O_9Cl_3$: c, 31.79; H, 1.85. Found: C, 31.95; H, 2.03. **5b**: colorless needles, mp 234° (84%), IR (KBr) 1840, 1815, NMR (CH_3CN) δ 6.67 (d, J=2 Hz, 1H), 6.27 (d, J=2 Hz, 1H), 5.25 (m, 5H). *Anal.* Calcd. for $C_{10}H_7O_9Cl_3$: C, 31.79; H, 1.85. Found: C, 31.69; H, 1.57. **5c**: colorless needles, mp 285—287° (80%), IR (KBr) 1835, 1805, NMR (CH_3CN) δ 6.61 (d, J=2 Hz, 1H), 6.20 (d, J=3 Hz, 1H), 5.15 (m, 5H). *Anal.* Calcd. for $C_{10}H_7Cl_3O_9$: C, 31.79; H, 1.85. Found: C, 31.70; H, 1.70. **5d**: This was obtained in a mixture of **5c** and **5d**.[21]

Conversion to Heptitols (8a,b,c,d)——The solutions of the photo-reduced telomers (**5a,b,c,d**) (0.1—0.2 mmol), in 80% CH_3OH (10—20 ml) were treated with $NaBH_4$ (0.5—0.8 mmol) under ice-cooling for 5 hr. To the reaction mixture was added an ion exchange resin (IR-120-BH^+) and the filtrate was evaporated *in vacuo*. After repeated flash-evaporations with CH_3OH (3 times), the resulting oil was treated with triethylamine (0.5 ml) in 75% CH_3OH (2 ml) at room temperature overnight. The reaction mixture was evaporated *in vacuo* to give the dichloro-polyols (**6a, b,c,d**) as an oily residue, which showed no absorption characteristic of ester groups in the IR spectrum and was used for the next step without further purification. A mixture of the poly-alcohols (**6a,b,c,d**) thus obtained and siliver nitrate (0.4—0.8 mmol) in water (8 ml) was stirred at 75° overnight. The precipitates were removed by filtration and the filtrate was treated with 1.2 N hydrochloric acid to remove excess silver ion. The insoluble materials were filtered off and the filtrate was neutralized with an ion exchange resin (Dowex-1 HCO_3^- form). To the aqueous solutions of the heptoses thus formed was added $NaBH_4$ (0.4—0.8 mmol) under ice-cooling and it was kept for 7 hr. The reaction mixture was treated with an ion exchange resin (IR-120-BH^+). Removal of the solvent followed by flash evaporation with CH_3OH (3 times) gave the heptitols (**8a,b,c,d**) as a syrup. The heptitols **8a, b** and **c** were identified as *threo* glycero-galacto-*erythro* glycero-ido- and meso glycero-ido-heptitols by gas-chromatographic analysis performed at 150° using 1.5% QF-1 and 2% XF-1105 columns. (Table I). Gas-chromatograms of the heptitol **8d** showed the peaks corresponding to *erythro* glycero-galacto-heptitol in addition to the samll peaks of **8c** due to the starting telomer **3d** contaminated with a small amount of isomer **3c**.

Table I. Retention Times of Heptitols

	1.5%QF–1 (150°)	2%XF–1105 (150°)
Heptitol (**8a**)	6.8 min	17.8 min
Heptitol (**8b**)	5.6	13.3
Heptitol (**8c**)	4.6	11.7
Heptitol (**8d**)	5.6	10.2
D-Glycero-L-galacto-heptitol[12]	6.8	17.8
D-Glycero-D-ido-heptitol[12]	5.6	13.3
meso-Glycero-ido-heptitol[12]	4.6	11.7
D-Glycero-D-galacto-heptitol[12]	5.6	10.2

1,1-Dichloro-aldehyde-"*erythro*"-glycero-ido-heptose (6b)——A solution of **5b** (620 mg, 1.64 mmol) in 90% CH_3OH (43 ml) was treated with $NaBH_4$ (311 mg, 8.2 mmol) under ice cooling for 6 hr. The reaction mixture was neutralized with an ion exchange resin (IR-120-B H^+). Removal of the solvent followed by

22) N. Mitsuo, T. Kunieda, and T. Takizawa, *J. Org. Chem.*, **38**, 2255 (1973).

flash-evaporation with CH_3OH (3 times) left a colorless powder (655 mg), which was extracted with acetone. The extracts were evaporated *in vacuo* to give an oily residue (644 mg). The resulting oil was chromatographed on silica gel with CH_2Cl_2–acetone (97: 3) to give the polyalcohol, whose remaining carbonate-rings were removed in 75% aq•CH_3OH (4 ml) by treatment with triethylamine (1 ml) at room temperature overnight. The reaction mixture was neutralized with an ion exchange resin (IR-120-B H^+). Removal of the solvent gave crude dichloromethyl compound **6b** (423 mg) as an amorphous powder, which showed no absorption of ester groups in the IR spectrum and was used for the next step without further purification. Treatment of **6b** with acetic anhydride in pyridine gave the hexaacetate as colorless crystals, mp 138° (from *n*-hexane–CH_2Cl_2), IR (KBr) 1760, 1240, NMR ($CDCl_3$) δ5.64 (*d*, $J=8$ Hz, 1H), 5.58 (m, 1H), 5.15 (m, 4H), 4.24 (m, 2H), 2.1 (m, 18H). *Anal.* Calcd. for $C_{19}H_{26}Cl_2O_{12}$: C, 44.10; H, 5.03. Found: C, 44.07; H, 5.03.

***erythro* Glycero-ido-heptose (7b), hexaacetate**——An aqueous solution (11 ml) of **6b** (423 mg) was stirred in the presence of silver nitrate (2.7 g, 16 mmol) at 75° overnight. The precipitate was removed by filtration and filtrate was treated with 1.2 N hydrochloric acid to remove excess siliver ion as silver chloride. The precipitate was filtered off and the filtrate was neutralized with an ion exchange resin (Dowex-1 HCO_3^- form). Evaporation of the filtrate gave **7b** as a syrup (117 mg, 42%), a part of which was reduced with borohydride to the heptitol with retention times of 5.6 min. (1.5% QF-1, 150°) and 13.3 min. (2% XF-1105, 150°), which were identical with those of the optically active authentic D-glycero-D-ido-heptitol.

Acetylation of **7b** with acetic anhydride in pyridine, gave the hexaacetate, which was recrystallized from *n*-hexane–CH_2Cl_2 to give colorless crystals, mp 150—150.5°, IR (KBr) 1760, 1240, NMR ($CDCl_3$) δ5.48 (d, $J=2$ Hz, 1H), 5.0 (m, 5H), 4.4 (m, 2H), 3.96 (m, 2H), 2.0 (m, 18H). *Anal.* Calcd .for $C_{19}H_{26}O_{13}$: C, 49.39; H, 5.63. Found: C, 49.10; H, 5.52.

5-(2,2-Dimethoxy-1-hydroxyethyl)-5′-trichloromethyl-[4,4′-bi-1,3-dioxolan]-2,2′-dione (9b, R=CCl_3)——According to the procedure described for ω-trichloropentoses from $n=2$ telomers[5], a solution of **3b** (1.03 g, 2.5 mmol) in absolute CH_3OH (50 ml) was refluxed for 55.5 hr in the presence of catalytic amount of *p*-toluene sulfonic acid (40 mg). The reaction mixture was evaporated *in vacuo*. The resulting oil was chromatographed on silica gel with CH_2Cl_2–acetone (95: 5) as an eluting solvent to give the acetal **9b** as an oily residue (216 mg) which showed bands at 3400 (OH) and 1820 cm^{-1} (C=O) in the IR spectrum and singlet peaks at δ3.48 and 3.54 assignable to two methoxy groups in the NMR spectrum.

7,7,7-Trichlo-7-deoxy-*threo*-glycero-gulo-heptose (11b, R=CCl_3), pentaacetate——A solution of the above **9b** (121 mg, 0.31 mmole) in 75% CH_3OH (2 ml) was treated with triethylamine (0.5 ml) at room temperature overnight. The reaction mixture was evaporated *in vacuo* to give an amorphous powder (113 mg) which showed no adsorption of the ester group in the IR spectrum. The powder was dissolved in a small amount of water. The insoluble materials were filtered off and the filtrate was neutralized by brief treatment with an ion exchange resin (IR-120-B H^+). Removal of the solvent *in vacuo* gave the acetal **10b** (86 mg, 82%) whose aqueous solution was treated with an ion exchange resin (IR-120-B H^+) under stirring at room temperature overnight. The reaction mixture was filtered. Evaporation of the filtrate gave **11b** as an oil (65 mg, 87.3%), which gave the pentaacetate as colorless crystals, mp 158° (from *n*-hexane–CH_2Cl_2), IR (KBr) 1760, 1220, NMR ($CDCl_3$) δ6.33 (d, $J=4$ Hz, 0.1 H), 5.65 (d, $J=8$ Hz, 0.9H), 5.0 (m, 4H), 4.52 (d-d, $J=9$ Hz, $J=2$ Hz, 1H), 2.1 (m, 15H). *Anal.* Calcd. or $C_{17}H_{21}Cl_3O_{11}$: C, 40.20; H, 4.14. Found: C, 40.17; H, 4.14.

7,7-Dichloro-7-deoxy-*threo*-glycero-gulo-heptose (11b, R=CH_2Cl_2), pentaacetate——A solurion of **5b** (530 mg, 1.40 mmol) in methanol (25 ml) was refluxed for 3 days in the presence of a catalytic amount of *p*-toluenesulphonic acid (30 mg). The reaction mixture was evaporated under reduced pressure to give the acetal **9b** (R=$CHCl_2$) as an oily residue (580 mg), which was purified by chromatography on silica gel with CH_2Cl_2–acetone (96: 4) as eluting solvents. The protecting groups were deblocked with triethylamine and an ion exchange resin (IR-120) in the same way as employed for **11b** (R=CCl_3) to give the deoxy heptose **11b** (R=$CHCl_2$) (345 mg) which was isolated and characterazed as pentaacetate (366 mg, y55.1% based on **5b** Crystallization from *n*-hexane–CH_2Cl_2 gave colorless crystals, mp 156—160°, IR (KBr) 1760, NMR ($CDCl_3$) δ 5.76 (d, $J=9$ Hz, 1H), 5.62 (d, $J=8$ Hz, 1H), 5.36 (d-d, $J=8$ Hz, $J=2$ Hz, 1H), 5.28—4.80 (m, 3H), 4.24 (d-d, $J=9$ Hz, $J=2$ Hz, 1H), 2.10 (m, 15H). *Anal.* Calcd. for $C_{17}H_{22}Cl_2O_{11}$: C, 43.13; H, 4.65. Found: C, 43.22; H, 4.72.

5-Dichloromethyl-5″-cyano-[4,4′: 5′,4″-ter-1,3-dioxolan]-2,2′,2″-trione (12b)——A solution of **5b** (518 mg, 1.4 mmol), in 80% aqueous ethyl acetate (12 ml) was treated with NaCN (74 mg, 1.5 mmol) in the presence of tetrabutylammonium bromide (35 mg) as a phase transfer catalyst under ice-cooling for 2 hr. The ethyl acetate layer was separated, washed with water (2 times) and dried over anhydrous sodium sulfate overnight. Removal of the solvent gave a semi-crystalline mixture (495 mg, 98.0%) of **12b** (cis) and **12b** (*trans*). Recrystallization from CH_3CN–CH_2Cl_2 gave colorless crystals which was apparently 1: 1 mixture of *cis*- and *trans*-cyanide, mp 250—251°, IR (KBr) 1825, NMR (CH_3CN) δ6.22 (d, $J=2$ Hz, 1H), 5.70 (d, 9 Hz, 0.5H), 5.56 (d, $J=4$ Hz, 0.5H), 5.10 (m, 5H). *Anal.* Calcd. for $C_{11}H_7Cl_2NO_8$: C, 35.87; H, 1.90; N, 3.80 Found: C, 35.40; H, 1.92; N, 3.43.

5-Dichloromethyl-5″-methoxycarbonyl-[4,4′: 5′,4″-ter-1-3-dioxolan]-2,2′,2″-trione (13b (*trans*))——Dry hydrogen chloride gas was moderately bubbled through a solution of a 1: 1 mixture of **12b** (*cis*) and **12b** (*trans*) (495 mg, 1.35 mmol) in absolute methanol (28 ml) under ice-cooling for 1 hr. The precipitates were

removed by filtration and the filtrate was evaporated *in vacuo* to give an oily residue (650 mg), which was chromatographed on silica gel with CH_2Cl_2-acetone (95: 5) as eluting solvents to permit the isolation of *trans*-isomer. Recrystallization from CH_2Cl_2–acetone gave the ester **13b** (86 mg, 15.9%) as colorless needles, mp 209—211°; IR-(KBr) 1830, 1805, 1755, 1150; NMR (CH_3CN) δ6.20 (d, J=2 Hz, 1H), 4.9—5.24 (m, 6H), 3.81 (s, 3H). *Anal.* Calcd. for $C_{12}H_{10}Cl_2O_{11}$: C, 35.91; H, 2.49. Found: C, 35.65; H, 2.39.

2,3-Dihydroxy-3-(5′-dichloromethyl-2,2′-dioxo-[5,4′-bi-1,3-dioxolan]-4-yl)propionamide(16b)——Further elution of the above column with more polar solvent ethyl acetate gave an amorphous powder (0.1 g) which was repeatedly purified by recrystallization from ethyl acetate to give colorless crystals, mp 118—119°. IR (KBr) 3200, 1830, 1795, 1655. *Anal.*, Calcd. for $C_{10}H_{11}Cl_2NO_9 \cdot H_2O$; C, 31.75; H, 3.44; N, 3.70. Found: C, 31.61; H, 3.29; N, 3.63.

***threo* Threo-ido-octose (15b), heptaacetate**——Trans-ester **13b** (237 mg, 0.59 mmol) was treated with $NaBH_4$ (223 mg, 5.9 mmol) in 90% EtOH (15 ml) at 60° for 3 hr. The reaction mixture was concentrated *in vacuo* and neutralized with an ion exchange resin (IR-120 H^+ form). The filtrate was evaporated *in vacuo* and repeated flash evaporation with methanol (4 times) gave **14b** as an amorphous powder (190 mg). The powder was treated with $AgNO_3$ (1.0 g, 5.9 mmol) in H_2O (6 ml at 75° for 24 hr. The precipitate was filtered off and excess silver ion was removed by addition of 1.2 N HCl to the reaction mixture. The filtrate was neutralized with an ion exchange resin (Dowex 1 HCO_3^- form) and evaporated *in vacuo* to give the octose **15b** (154 mg) which was purified as the hepraacetate (y. 30% based on **13b**), mp 195—197° (from EtOH–*n*-hexane), IR (KBr) 1760, NMR ($CDCl_3$) δ5.6—5.0 (m, 5H), 4.4—3.8 (m, 4H), 2.1 (m, 21H). *Anal.* Calcd. for $C_{22}H_{30}O_{15}$: C, 49.44; H, 5.62. Found: C, 48.84; H, 5.76.

Conventional reduction of the ocotose **15b** with $NaBH_4$ gave the octitol which was identifed as *threo* threo-ido-octitol by glc. analysis using 1%XF-1105 column (Table II).

Table II. Retention Times of Octitols

	1%XF–1105 (140°)
Octitol from **15b**	4.5 min
D-*threo*-L-Ido-octitol[20]	4.5
D-*erythro*-L-galacto-octitol[20]	4.9
D-*erythro*-D-Galacto-octitol[20]	3.9
D-*threo*-L-Galacto-octitol[20]	5.3

2-(2-Chloro-1-hydroxyethyl)-5-chloromethyl-1,3-dioxolan-4- ol, diacetate (20)——Dichloromethyl Compound **19** (500 mg, 1.35 mmol.) derived from n=1 telomer **17** was treated with tri-*n*-butyltin hydride,[17] which was generated *in situ* from a mixture of tri-n-butyltin oxide (1.60 g, 2.70 mmol) and polymethyl siloxane (0.324 g, 5.40 mmol.), in boiling benzene (2.5 ml) under nitrogen gas. The reaction mixture was evaporated *in vacuo* to leave an oily residue (2.304 g), which was submitted to chromatography on silica gel with benzene as an eluting solvent to afford the chloromethyl derivative **20** (4) (as an oil, 237 mg, y 58.3%), IR (Neat) 1760, NMR ($CDCl_3$) δ 6.24 (d, J=2 Hz, 1H), 5.42 (d, J=4 Hz, 1H), 5.20 (d-t, J=2 Hz, J=4 Hz, 1H), 4.34 (d-t, J=2 Hz, J=4 Hz, 1H), 3.70 (m, 4H), 2.12 (m, 6H), MS: *m/e* 244, 242 240 (M^+-OAc), 178 (base).

2-(1-Hydroethyl)-5-methyl-1,3-dioxolan-4-ol, diacetate (21)——Compound **19** (500 mg, 1.35 mmol). was treated with di-*n*-butyltin di-hydride (3.718 g, 1.58 mmol), generated from a mixture of di-*n*-butyltin oxide (12.5 g, 0.05 mol) and polymethyl siloxane (6.0 g, 0.1 mol), in boiling benzene (1.5 ml) for 24 hr under nitrogen gas. Evaporation of the reaction mixture left the oily resicue (3.745 g) which was roughly chromatographed on silica gel with CH_2Cl_2 (300 ml) as an eluting solvent. Rechromatography of the crude products (1.45 g) on silica gel with benzene afforded the dimethyl compoumd **21** as an oil (114 mg, y 36.4%) in addition to a small amount of **20** (12 mg, 3.0%), IR (Neat) 1750, NMR ($CDCl_3$), δ5.90 (d, J=2 Hz, 1H), 5.18 (d, J=4 Hz, 1H), 5.0 (m, 1H), 4.20 (d-q, J=2 Hz, J=6 Hz, 1H), 2.08 (m, 6H), 1.34 (d, J=6 Hz, 3H), 1.26 (d, J=6 Hz, 3H), MS: *m/e* 232 (M^+, weak), 173 (M^+—OAc), 145 (base).